Larval stages, habitat and distribution of the hyperoliid frog *Heterixalus rutenbergi* (Boettger, 1881)

Liliane RAHARIVOLOLONIAINA[*], David R. VIEITES[**], Frank GLAW[***] & Miguel VENCES[****]

* Université d'Antananarivo, Département de Biologie Animale, Antananarivo, Madagascar
** Departamento de Bioloxía Animal, Laboratorio de Anatomía Animal, Buzon 137, Facultade de Ciencias Bioloxicas, Universidade de Vigo, Apdo. 874, 36200 Vigo, Spain
*** Zoologische Staatssammlung, Munchhausenstr. 21, 81247 Munchen, Germany
**** Institute for Biodiversity and Ecosystem Dynamics, Zoological Museum, University of Amsterdam, PO Box 94766, 1090 GT Amsterdam, The Netherlands
<vences@science.uva.nl>

We describe the hitherto unknown external larval morphology of *Heterixalus rutenbergi*, a reed frog from highlands in central Madagascar. Tadpoles were collected in a sun-exposed pond in a swampy savannah at the Itremo Massif. Their morphology is similar to that of other *Heterixalus*, with a labial tooth row formula of 1/1+1:2. They differ by a distinct marbled or spotted color on the proximal third of the caudal musculature. Metamorphosing juveniles have the distinctive pattern of adult frogs with five white stripes on a green dorsum, unlike other *Heterixalus* who show a juvenile coloration with two dorsolateral stripes. Contrary to other *Heterixalus* species, *H. rutenbergi* seems to be restricted to highland savannahs and has so far not been recorded in high densities; its status should therefore be more carefully monitored.

INTRODUCTION

The genus *Heterixalus* Laurent, 1944 contains the endemic Malagasy representatives of the family Hyperoliidae. *Heterixalus* is the sister group of the Seychellean *Tachycnemis* Fitzinger, 1843 in this otherwise exclusively African family (RICHARDS & MOORE, 1996, VENCES et al., 2003). Currently 10-11 species of *Heterixalus* are known (VENCES et al., 2000), two of which are endemic to the highlands of central and central-eastern Madagascar: *H. betsileo* (Grandidier, 1872) and *H. rutenbergi* (Boettger, 1881).

Heterixalus species are typical inhabitants of open areas, and often occur in secondary habitats such as rice fields. Their larvae are of a rather generalized pond type, with a single uninterrupted row of labial teeth on the upper lip, and one interrupted and two uninterrupted rows on the lower lip. This morphology has been ascertained by BLOMMERS-SCHLOSSER (1982) and GLAW & VENCES (1993, 1994) for *H. betsileo*, *H. madagascariensis* (Dumeril & Bibron, 1841), *H. boettgeri* (Mocquard, 1902) and *H. luteostriatus* (Andersson, 1910).

Heterixalus are also very uniform in adult morphology, and a reliable species distinction is only possible by combining advertisement calls and coloration in life (Glaw & Vences, 1993). However, one species, *H. rutenbergi*, has a number of highly divergent traits: its call bears no resemblance to that of any other species, the gular gland on the vocal sac of males has blackish color, and the dorsal pattern (green with five longitudinal white bands) is unique. We recently started with intensive herpetological surveys in the montane areas of central Madagascar (see Vences et al., 2002). During the fieldwork, we discovered tadpoles that could be unambiguously assigned to *H. rutenbergi* by the pattern of metamorphosing juveniles. In the present paper, we describe the morphology of these tadpoles and review the published information on distribution and habitat of *H. rutenbergi*.

Materials and methods

Tadpoles were collected on 11 March 2001 at Ambatomenaloha, Itremo Massif, central Madagascar (19°58'S, 46°55'E; 1820 m above sea level). They were found in a shallow sun-exposed pond on a large unforested plain that partially was flooded by a river. Most ponds on this plain were fed by the river and had relatively cold water, whereas the ponds populated by *Heterixalus* tadpoles were much warmer, but no measurements of temperature could be effectuated. The pond had a depth of ca. 60 cm, and was bordered by grass only. The specimens were preserved in 5% formalin after capture, but were damaged during the transport. A batch of 14 tadpoles were deposited in the herpetological collection of the Zoologische Staatssammlung München under the number ZSM 789.2001. One additional specimen (field number LR 271) used for the detailed morphological description and drawings will be incorporated in the ZSM later on. Developmental stages are described after Gosner (1960). Morphological measurements were taken by L. R. using a digital caliper to the nearest 0.1 mm, following landmarks, terminology and definitions of McDiarmid & Altig (1999). The formula of labial tooth rows follows Dubois (1995).

We use the following abbreviations: BL, head and body length (in tadpoles: from the tip of the snout to the junction of the posterior body wall with the axis of the tail myotomes, McDiarmid & Altig 1999), TAL, tail length, BW, maximum body width; ODW, maximum width of oral disc; DGMP, dorsal gap of marginal papillae, IOD, interorbital distance between centers of pupils; ED, eye diameter, TH, tail height at beginning of tail; MTH, maximum tail height including the caudal fin; TMH, height of caudal musculature at mid-tail, TMW, caudal muscle width, SVL, snout-vent length (in adult and juvenile frogs), UTR, upper tooth row; LTR, lower tooth row.

Results

The series of tadpoles assigned to *Heterixalus rutenbergi* had a conspicuous color pattern. They were brownish with green olive, and had a very distinct silvery white marbling on the proximal third of the caudal musculature (fig. 1a-b). In late developmental stages

(42-45) the typical adult coloration (green dorsum with five white longitudinal stripes, each bordered by two black lines) became visible (fig. 1c).

The following morphological description is based on one tadpole in stage 37 (field number LR 271, fig 2a-c). Tail only partly preserved, part of the skin detached. A rather compressed tadpole of ORTON's (1953) type 4; eyes directed laterally, spiracle sinistral and positioned closer to the anus than to the tip of snout; caudal fin, as far as recognizable, dorsally and ventrally with straight edges, starting directly behind body (fig 2b); intestine not visible through the ventral skin. Further proportions and detailed characters of body and tail not reliably assessable because of poor state of preservation.

Oral disc apparatus in excellent state of preservation (fig. 2c), generalized, small, almost terminal, oriented ventrally, labial tooth row formula 1/1+1,2; tooth rows distinct but relatively small; LTR1 with a small gap (< 0.1 mm); UTR1 with approximately 80 labial teeth (ca. 34 per mm). Oral disc without a recognizable lateral notch; beak distinct and black, both jaw sheaths with serrations at their cutting edges. Oral papillae present around the oral disc except for its upper part, 1-2 rows of submarginal papillae, restricted to lateral parts of oral disc; marginal papillae in one row; altogether about 37 marginal and 8-10 submarginal papillae, all shorter than 1 mm.

Morphometric measurements. BL 14.4 mm; TAL (incomplete) 14 9 mm; BW 9 4 mm, ODW 1.7 mm, DGMP 1 7 mm; IOD 5 6 mm; ED 2.1 mm, TH 5.4 mm, MTH 8.8 mm, TMH 4.8 mm, TMW 3.5 mm; UTR1 1.9 mm; each part of LTR1 0 8 mm; LTR2 1.8 mm; LTR3 0 7 mm

In preservative, anterior lateral surface of body dark brown with yellowish shade, posterior part dark brown with some larger silvery shades, whole dorsum dark brown with many black spots of 0.4-1.6 mm diameter (fig. 2a-b) Similar spots also on dorsal and ventral caudal fins, and on caudal musculature (0 6-2 3 mm in diameter) Belly white with many smaller black spots.

In a just metamorphosed juvenile (fig 1c), the color pattern typical for adult *H rutenbergi* was already fully expressed SVL of one specimen in stage 41-42 belonging to the series ZSM 789.2001 is 15.5 mm.

No adult *H rutenbergi* were found during our survey at Itremo. Other frog species collected or observed by us were *Boophis ankaratra* Andreone, 1993, *B. goudoti* Tschudi, 1883, *B luteus* (Boulenger, 1882) (call record), *B. microtympanum* (Boettger, 1881), *Mantidactylus* aff *brevipalmatus* Ahl, 1929, *M domerguei* (Guibé, 1974) (call record), *M femoralis* (Boulenger, 1882), *M lugubris* (Duméril, 1853), *M* sp. A. aff. *curtus* (Boulenger, 1882), *M* sp. B aff. *curtus* and *Ptychadena mascareniensis* (Dumeril & Bibron, 1841). Furthermore, a collection made by D Rakotomalala included a subadult specimen of *Scaphiophryne madagascariensis* (Boulenger, 1882).

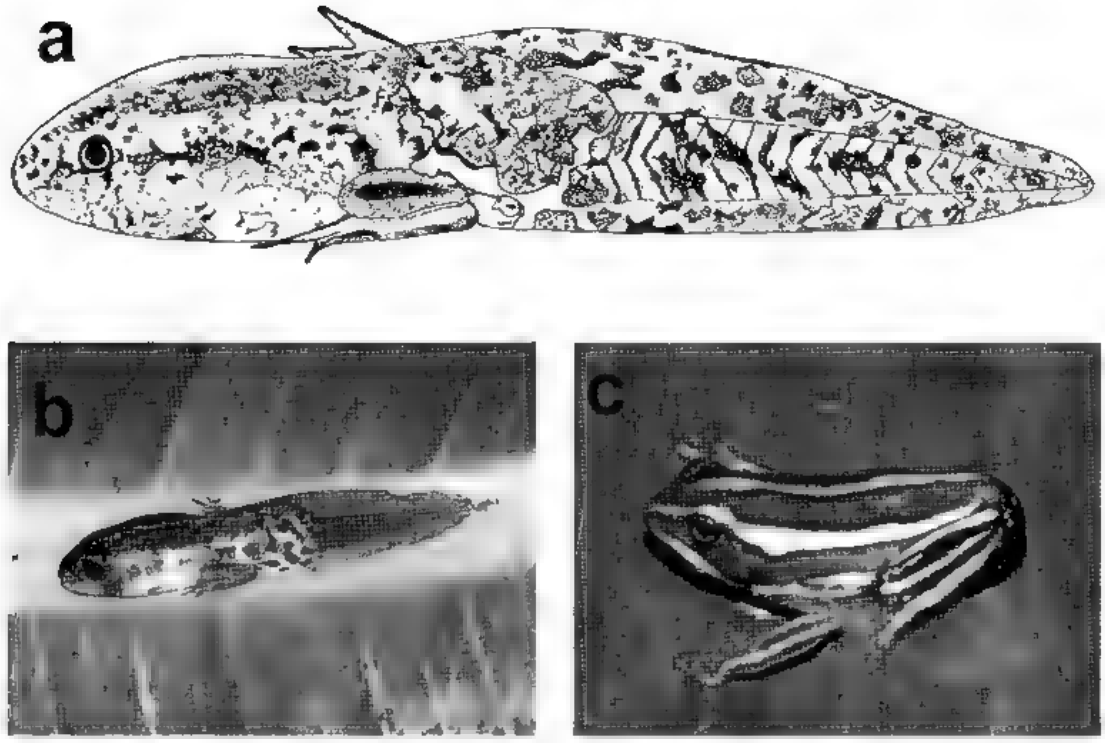

Fig. 1. Drawing and photographs of larval stages of *Heterixalus rutenbergi* from Ambatomenaloha, Itremo, central Madagascar (a), drawing of a tadpole in life, based on a color photograph; (b), photograph of another tadpole specimen in life, (c), photograph of a metamorphosing juvenile (tail not yet fully reduced), already showing the typical adult coloration. Both photographs were made on 12 March 2001.

Discussion

Assigning tadpoles to adult frogs is a difficult endeavour, and the decisions often remain tentative, except for cases in which (1) tadpoles are identified by means of genetic markers, (2) tadpoles are raised from clutches deposited by well-identified adult specimens, (3) metamorphosed juveniles are raised to the adult stage, (4) metamorphosed juveniles already show characters that are fully diagnostic for the particular species. The case of the tadpoles described herein belongs into the fourth category, and their assignment to *Heterixalus rutenbergi* is based on the following rationale. (1) They have the typical *Heterixalus* tooth formula (see below) which is not found in any other group of Malagasy frogs (Glaw & Vences 1994). (2) No other *Heterixalus* species is known from Itremo (Glaw & Vences 1994), and during our survey we did not hear any call assignable to a *Heterixalus* species. (3) The larval color pattern on the flanks is different from that of the other known *Heterixalus* tadpoles, among which the only other species known to occur in the central highlands and adjacent western savannahs, *H. betsileo* and *H. luteostriatus*. (4) One specimen of the batch ZSM 789/2001 in stages 41-42 (forelimbs fully emerged, but larval mouthparts still present) still has the characteristic larval color pattern on the flanks but also shows a central, two

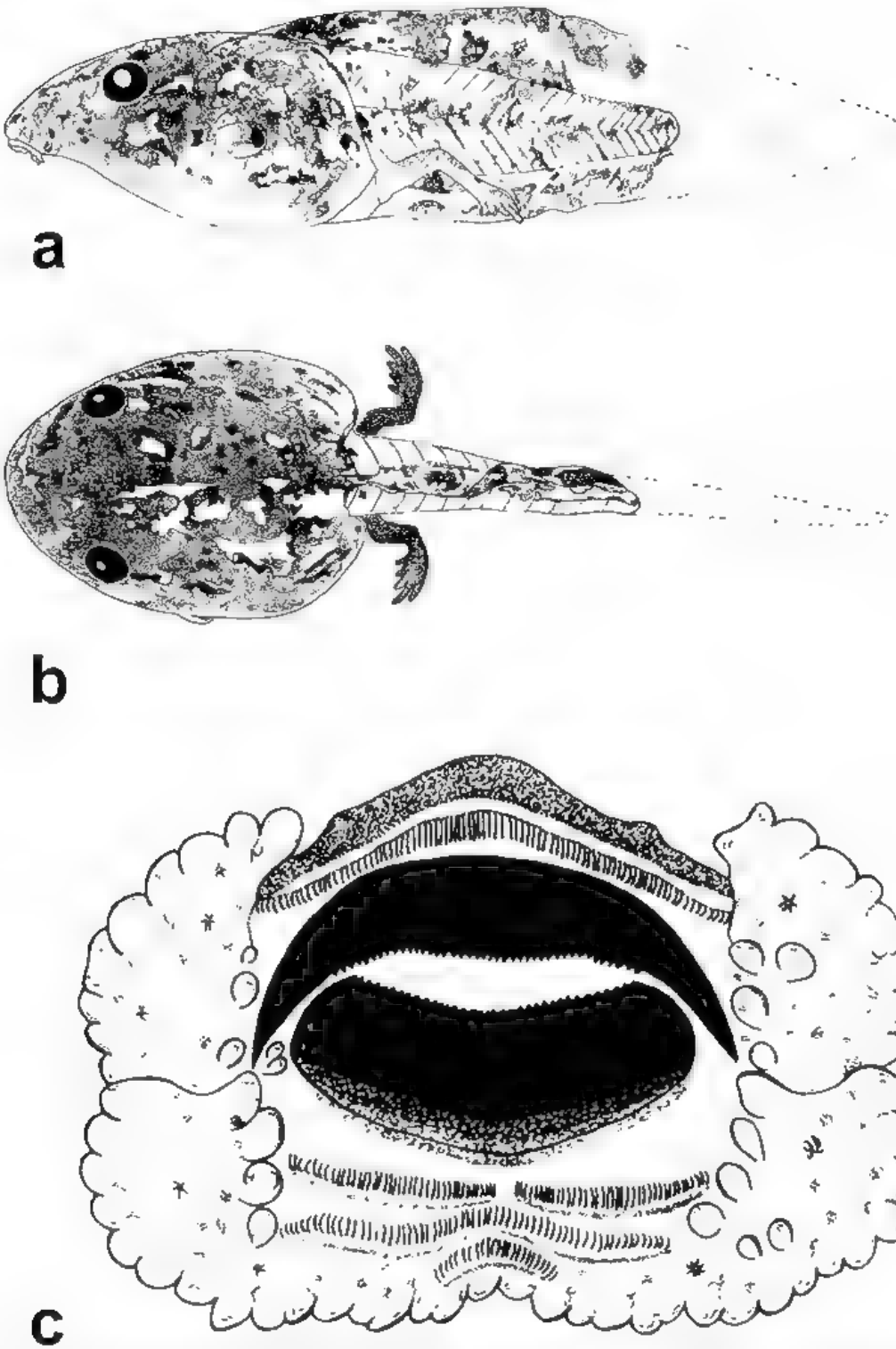

Fig. 2 Drawings of preserved tadpole specimen of *Heterixalus rutenbergi* from Ambatomenaloha, Itremo, central Madagascar, specimen LR 271 (developmental stage 37) (a) lateral view, (b) dorsal view, (c) mouthparts. Not to scale. Sharply delimited white patches in lateral and dorsal views symbolize detached skin

dorsolateral and two lateral light stripes. (5) This five-striped pattern, which is fully developed in specimens in stages 45-46, is absent in all other *Heterixalus* and indeed also in all other Malagasy frog species (GLAW & VENCES, 1994), including all taxa reported from Itremo. Hence, this character reliably characterizes the tadpole specimens as *Heterixalus rutenbergi*

According to the data provided herein, general larval morphology of *H. rutenbergi* is similar to that of other *Heterixalus*. However, tadpoles of this species have a conspicuous color and distinct differences regarding the transition to the adult pattern. The adult coloration in *Heterixalus* is very diverse, and important differences can be observed within and among conspecific populations (GLAW & VENCES, 1993, 1994). Some species are characterized by a pair of light dorsolateral stripes. This pattern seems to be always present in adult *H. betsileo*, *H. carbonei* and *H. luteostriatus* (with the exception of *H. betsileo* from Ankaratra, in which the stripes are almost unrecognisable). Other species do not display this pattern as adults. However, two species of uniform adult coloration (*H. boettgeri* and *H. madagascariensis*) have dorsolateral stripes as juveniles, as do *H. andrakata*, *H. betsileo* and *H.* "*variabilis*" (GLAW & VENCES, 1993). *H. rutenbergi* differs from this trend because its five stripes appear simultaneously already at metamorphosis. Also the final color (dark green) was present from stage 45 onwards. This means that, in contrast to other *Heterixalus* species, a typical juvenile coloration is lacking in *H. rutenbergi*.

A second aspect that merits attention is the conspicuous silvery white marbling on the proximal portion of the tail of *H. rutenbergi* tadpoles. This pattern is not known from any other *Heterixalus* tadpoles (BLOMMERS-SCHLÖSSER, 1982; GLAW & VENCES, 1994), but it reminds the tadpoles of the African hyperoliid genus *Kassina* that are also pond-dwellers (with very high fins, however) and display brightly striped or mottled patterns (e.g., CHANNING, 2001).

Heterixalus rutenbergi is known from six precise localities, all on the central high plateau of Madagascar: Ambohitantely, Mantasoa, Ambatolampy, Tsinjoarivo, Itremo and Ambatofitoharanana (BLOMMERS-SCHLÖSSER & BLANC, 1991; GLAW & VENCES, 1994; VALLAN, 2000). Because it is not a forest species, *H. rutenbergi* has not been recorded in most herpetological highland surveys, which did not focus on unforested areas. It seems clear, however, that the habitat choice of this species is more specialized than in its congeners that populate in huge densities all types of secondary habitats and even occur in flooded areas within towns. At Ambatolampy, we found *H. rutenbergi* in low densities in a moorland area, whereas *H. betsileo* was very common in the rice fields around the town (VINCES et al., 2002). At Mantasoa we were not able to confirm the presence of the species despite its characteristic calls that can be recognized over long distances (pers. obs.). Our findings in Itremo also refer to a relatively special highland savannah habitat. Certainly, the species is widespread over central Malagasy highlands, but its populations may have low densities and be vulnerable to transformation of moorland into rice fields. Additional fieldwork is needed to ascertain its habitat requirements and conservation status.

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